Hybrid Rocket Cold-Flow Modeling

Wendy Cruit/EP12
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Due to recent renewed interest in hybrid rocket motors, MSFC has participated in several hot-fire hybrid test programs. A major concern in several of these tests has been low-frequency pressure oscillations within the motor combustion chamber. The Propulsion Laboratory's Motor Systems Division, in conjunction with Auburn University's Dr. Rhonald Jenkins, submitted a Center Director's Discretionary Fund proposal to investigate such oscillations (approved September 1995). Through ongoing research at MSFC's Structures and Dynamics Laboratory, Fluid Dynamics Division, some of the mechanisms causing the oscillations are now being studied. A laboratory-scale, two-dimensional, water-flow model of a hybrid rocket motor has been built and installed in a closed-loop, water-flow facility to aid in the research.

The hybrid model is patterned after a shear-flow water tunnel developed in 1990 to investigate fluid-flow exiting porous materials.[1] The side walls are constructed of clear acrylic for flow visualization and optical velocity measurements; the top and bottom walls are constructed of a porous metal plate that simulates a solid propellant burning surface, the fuel of a hybrid motor. Oxidizer flow is also simulated with water and enters through an injector of axial or radial orientation (fig. 56). Reference figure 57 for a hybrid cold-flow model installed in a test fixture.

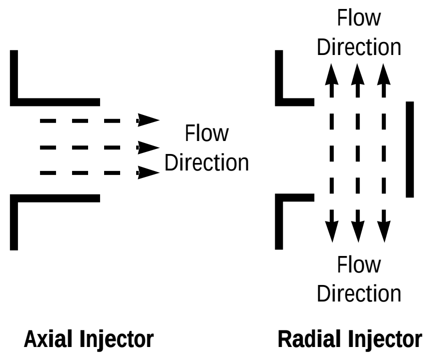

FIGURE 56.—Diagram showing flow direction of axial and radial injectors.

Flow interaction between the hybrid injector and motor sections is qualitatively understood by injecting helium bubbles and recording their movement with a 1,000-frames-per-second video recorder. Currently, the flow patterns are being assessed for the different configurations in the head end and immediately downstream of the head end. The vortex shedding frequencies are also being studied to determine if there is an association between the shedding frequency and the low-frequency pressure oscillations.

Quantitative flow-field mapping is accomplished with a laser Doppler velocimeter. Velocity vectors are constructed from the two components and show the recirculation zones created by the radial injector and the stagnation regions resulting from "flame-holding" steps in the diameter between the injector and motor (fig. 58).

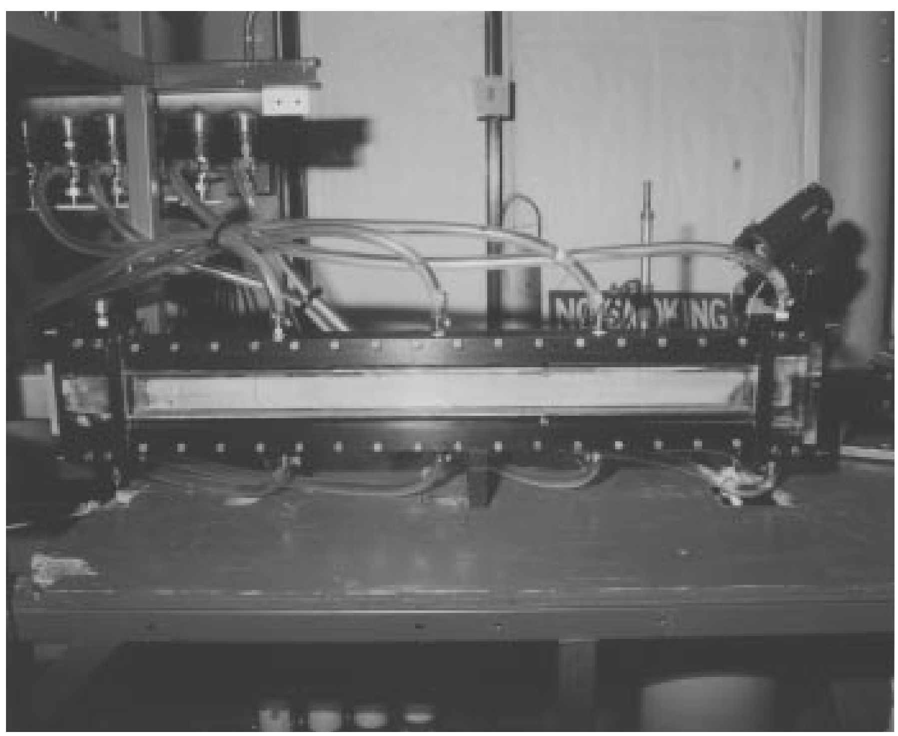

FIGURE 57.—Hybrid cold-flow model installed in test fixture.

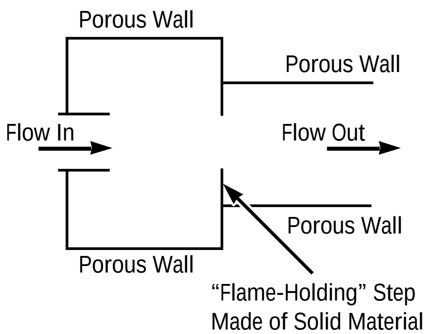

FIGURE 58.—Diagram of model showing "flame-holding" steps.

This hybrid modeling effort is contributing to the hybrid community by generating a parametric data base of the fluid dynamics in such motors and providing test-bed capability to answer current hybrid rocket motor questions and those that will arise in the future.

[1]Smith, A. 1993. Porous Wall Flow Experimental Facilities. *Research and Technology 1993*, 178–179.

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